[6] SOLAR ENRGY

- The type of radiation coming from the Sun depends on temperature.
- The Sun is emitting electromagnetic radiation in wide variety of wavelengths.
- Theoretical plot of the energy emitted by three perfect blackbody radiators of different temperature..
- The Sun radiates 1.6×10^7 watts of power per square meter from its surface at all wavelengths.
- People think solar-powered calculators or satellites, they convert light directly into electricity via the photoelectric effect.
- Photovoltaic systems are not the only way to convert sunlight into electricity.
- Solar Energy Industries Association (SEIA) reports that 94 percent of PV modules used today are made of crystalline silicon.
- Solar thermal electrical systems use sunlight in order to boil water for a turbine generator.
- Simple and widely used applications of solar thermal energy include solar water heating, swimming pool heating and agricultural drying.
- Flat-plate collectors large, insulated metal boxes with glass or plastic covers and dark heat absorbing plates are the most common collectors used for home solar water and space heating.
- Other common varieties are evacuated-tube collectors and integral collector storage systems.
- The intensity of solar energy at any point in
- the solar system is inversely proportional to the square of its distance from the sun
- $I \propto 1/d^2$

- In general terms, the amount of light stays the same, but it is spread over an increasingly larger area as you move away from the light source, so the intensity is less.
- When considering the intensity of solar radiation on the nine planets of the solar system, it is sometimes useful to think of relative intensity, a ratio comparing the solar intensity to that on Earth.
- One astronomical (AU) unit is defined as the mean Earth sun distance, which is (rounded to 150 million km)

[7] WIND ENRGY

Windmills have been used for many centuries for pumping water and milling grain.

In developing countries:
Water supply and irrigation (wind pumps) and electrical generation (wind generators).

$$\text{Power} = \frac{\text{density of air x swept area x velocity cubed}}{2}$$

$$P = \tfrac{1}{2}.\rho.A.v^3$$

Power density in the wind range
10 W/m² at 2.5 m/s (a light breeze)
41,000 W/m² at 40 m/s (a hurricane)

Wind power influences:

- Conversion systems Design
- Construction
- Siting
- Usage
- Economy

In large areas of the world appear below 3 m/s, where wind power may or may not be an attractive option.

The basic features that characterize lift and drag are:

1- Drag is in the direction of air flow
2- Lift is perpendicular to the air flow
3- Generation of lift always causes a certain amount of drag to be developed
4- With a good aerofoil, the lift produced can be more than thirty times greater than the drag
5- Lift devices are generally more efficient than drag devices

Types and Characteristics of Windmill Rotors
Vertical axis machines
Horizontal axis machines

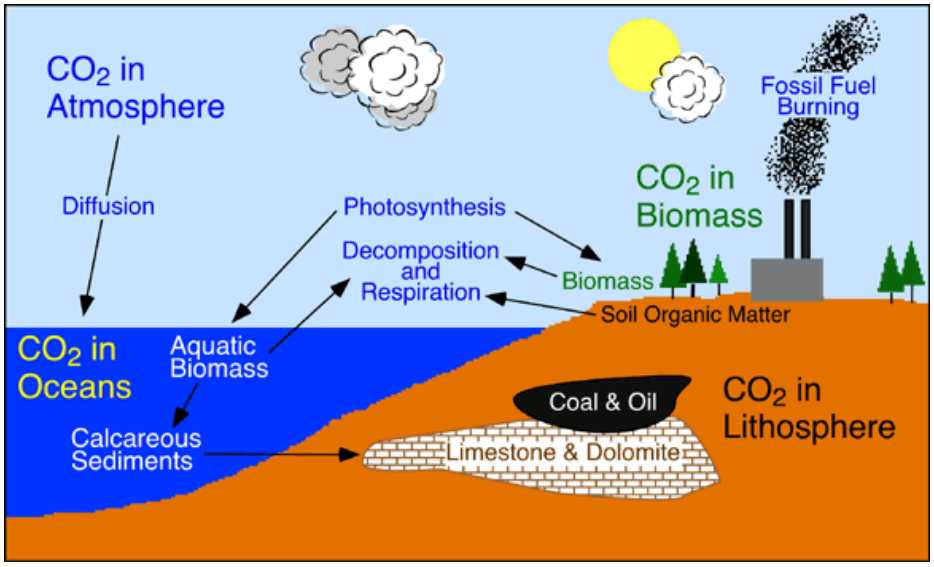
Several technical parameters characterize windmill rotors.

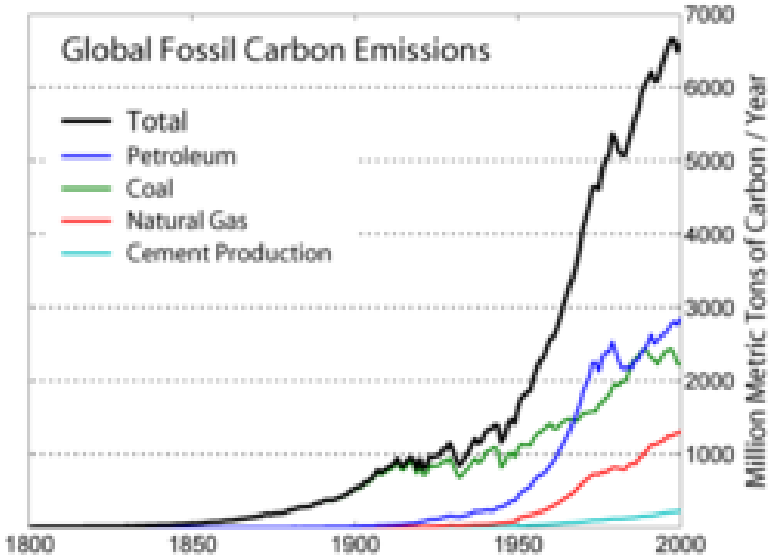
$$\text{Tip speed ratio} = \frac{\text{Bade tip speed}}{\text{Wind speed}}$$

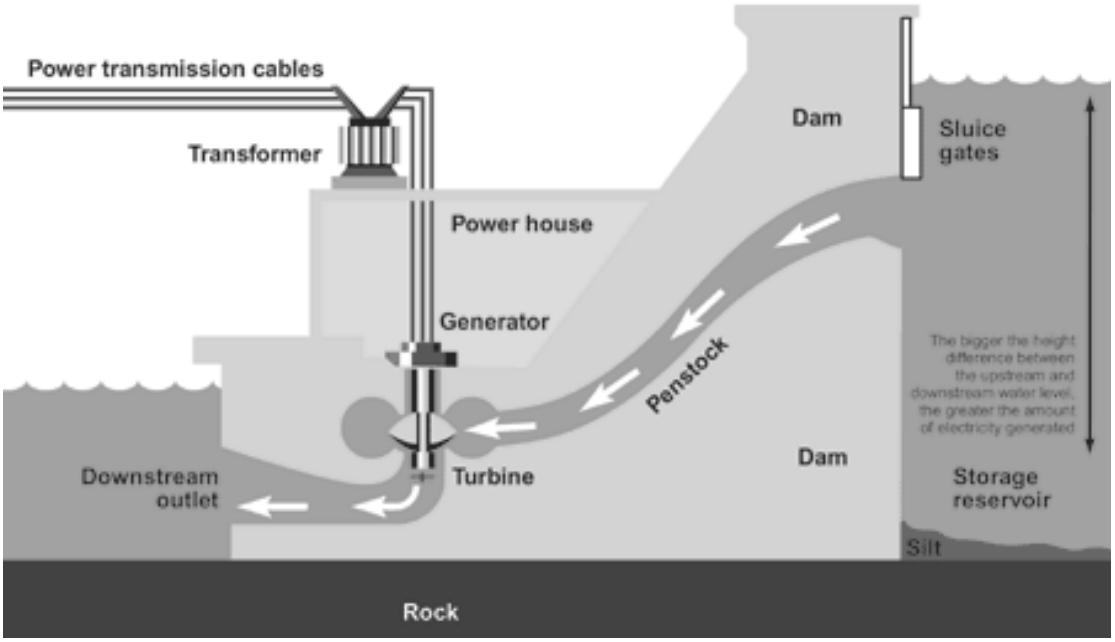
power in the wind that the rotor can extract is
Cp = coefficient of performance
Maximum of 59.3% (Betz limit)
In practice real wind rotors Cp in the range of 25%-45%.

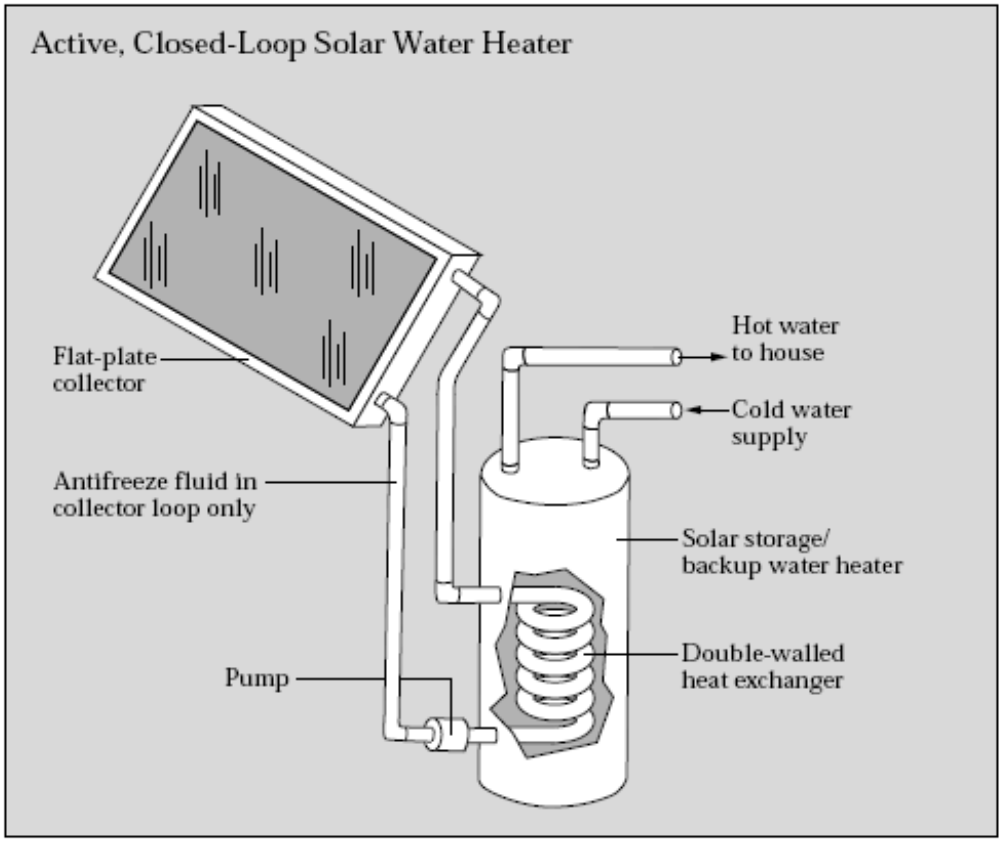
High-solidity machines carry a lot of material and can generate much higher starting torque.

The extra materials also cost more money.


CO_2 in Atmosphere
Diffusion
Photosynthesis
Decomposition and Respiration
Biomass
Soil Organic Matter
CO_2 in Biomass
Fossil Fuel Burning
CO_2 in Oceans
Aquatic Biomass
Calcareous Sediments
Coal & Oil
Limestone & Dolomite
CO_2 in Lithosphere

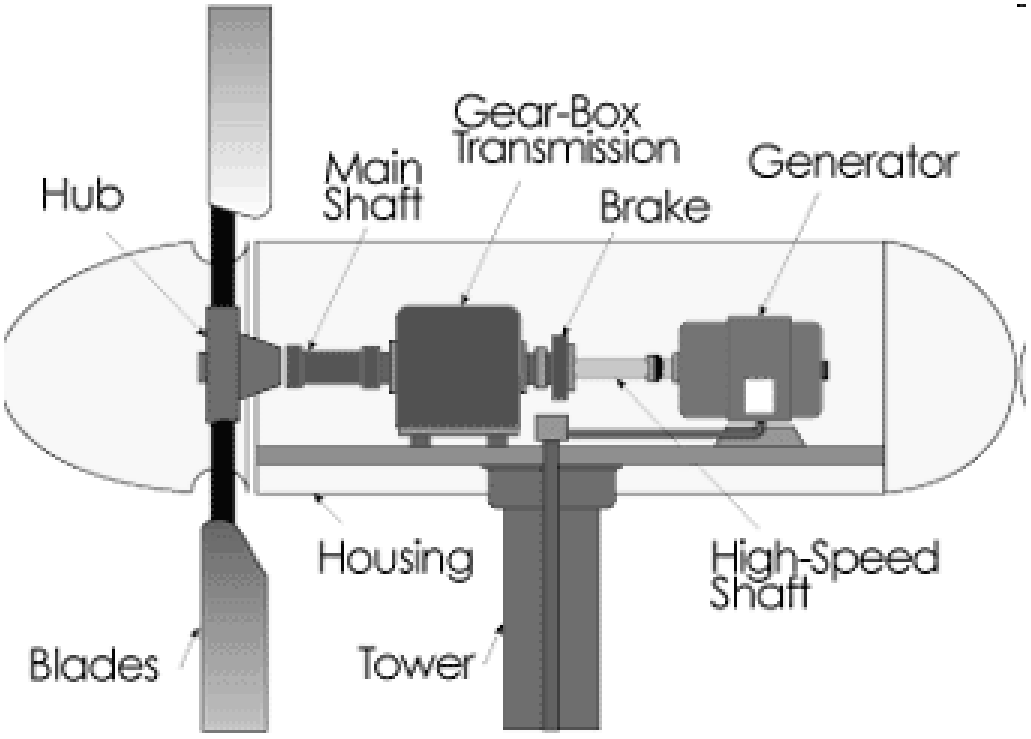

Global Fossil Carbon Emissions
Total
Petroleum
Coal
Natural Gas
Cement Production
7000
6000
5000
4000
3000
2000
1000
Million Metric Tons of Carbon / Year
1800
1850
1900
1950
2000

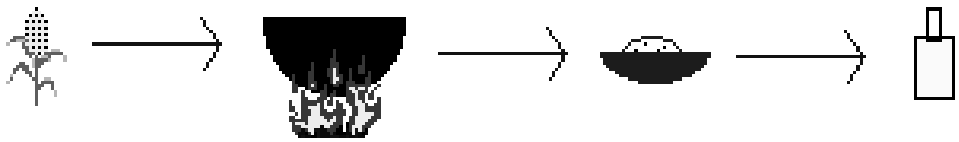

Power transmission cables
Transformer
Dam
Sluice gates
Power house
Generator
Penstock
The bigger the height difference between the upstream and downstream water level, the greater the amount of electricity generated
Dam
Downstream outlet
Turbine
Storage reservoir
Silt
Rock


Active, Closed-Loop Solar Water Heater
Flat-plate collector
Hot water to house
Cold water supply
Antifreeze fluid in collector loop only
Solar storage/ backup water heater
Pump
Double-walled heat exchanger

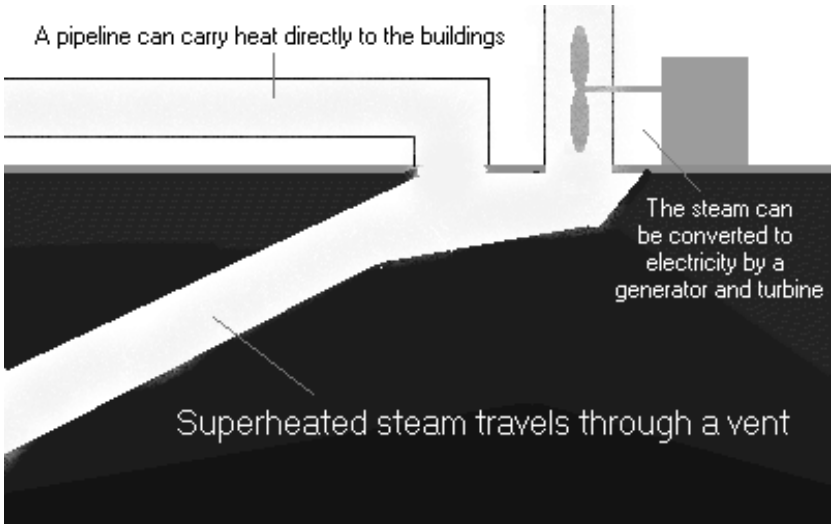

www.corbis.com

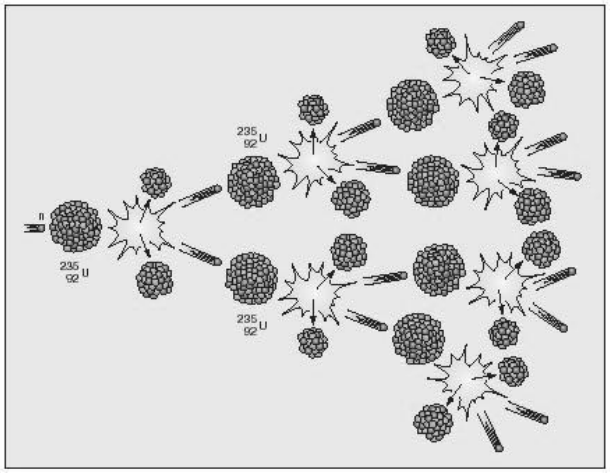
-

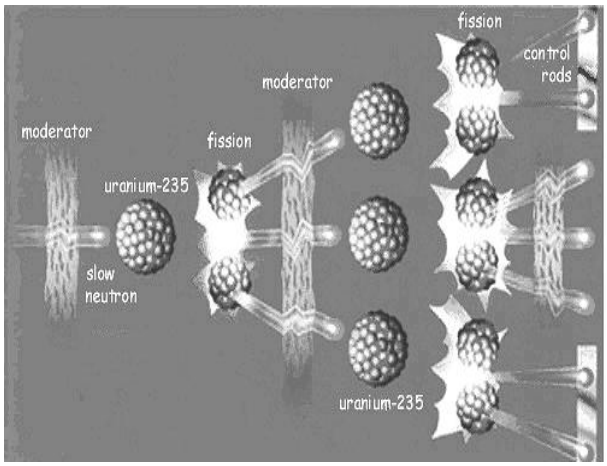

Hub
Main Shaft
Gear-Box Transmission
Brake
Generator
Housing
High-Speed Shaft
Blades
Tower

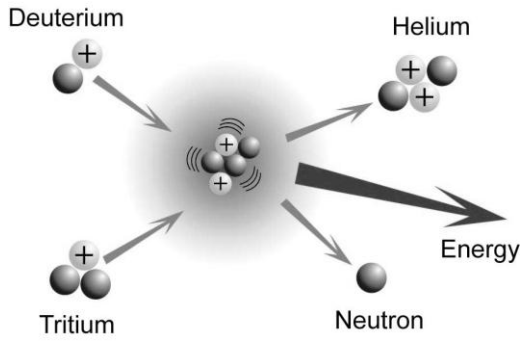


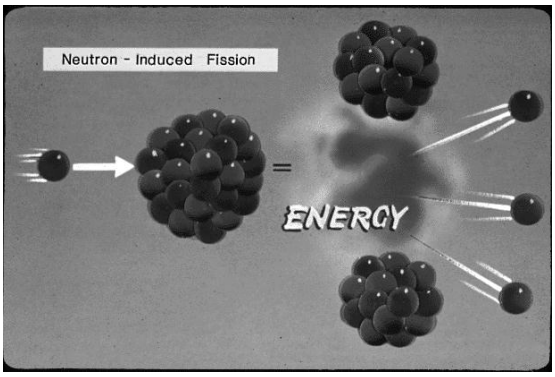
starch is heated to produce sugar, which is then fermented into alcohol

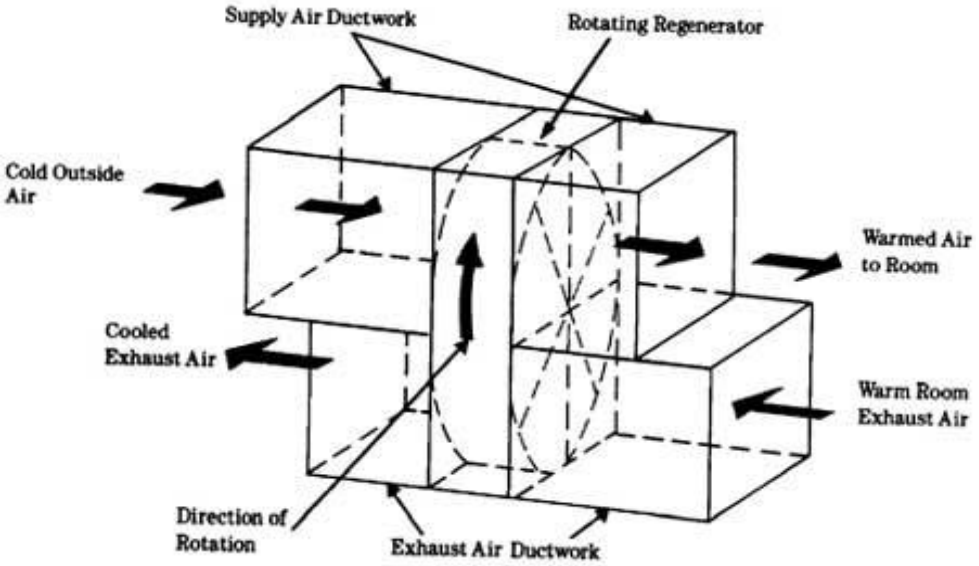


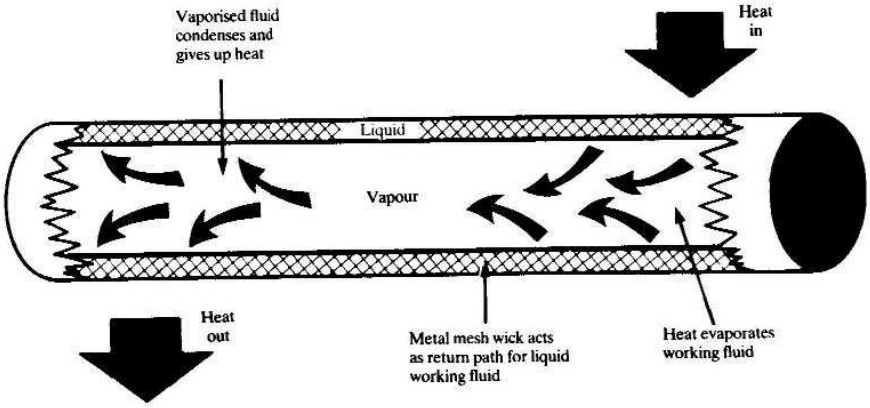


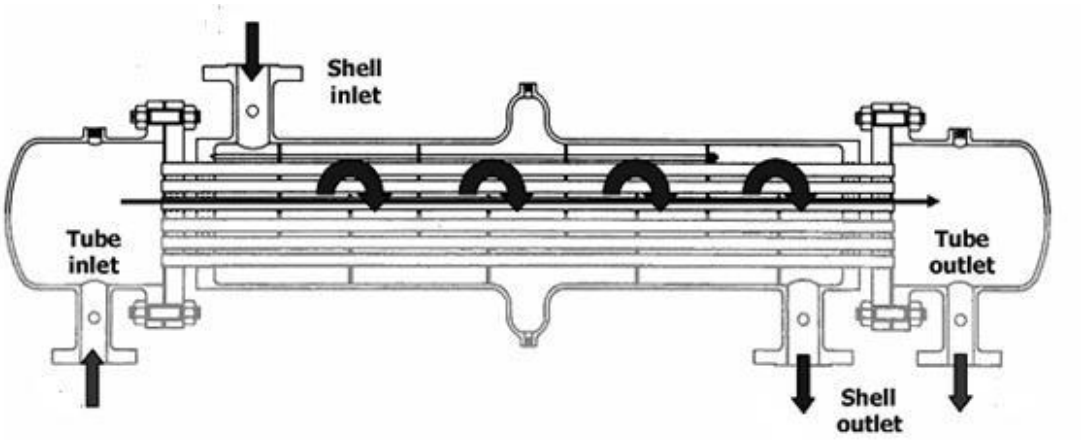


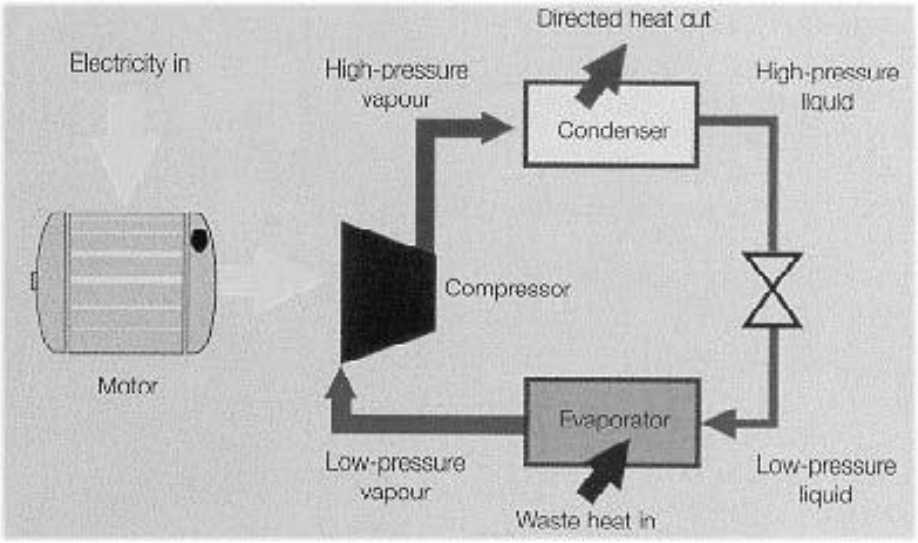

Deuterium
Helium
Energy
Tritium
Neutron

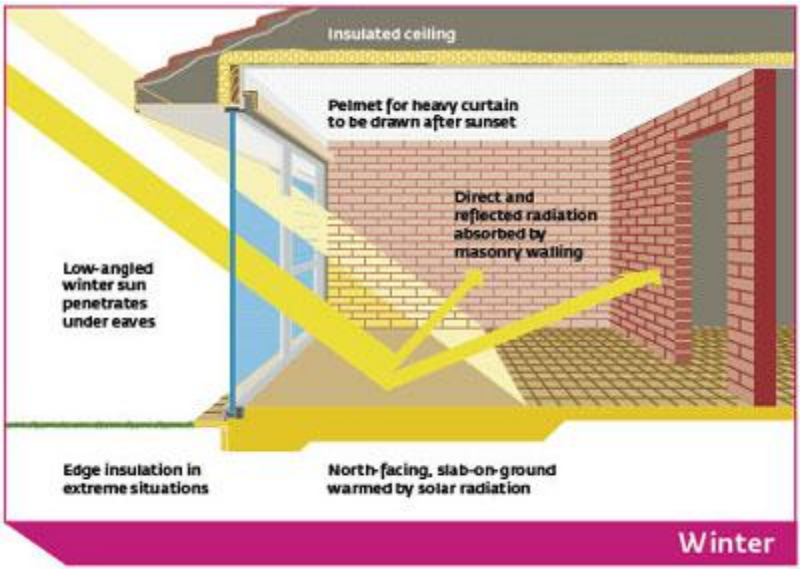

Neutron - Induced Fission
ENERGY

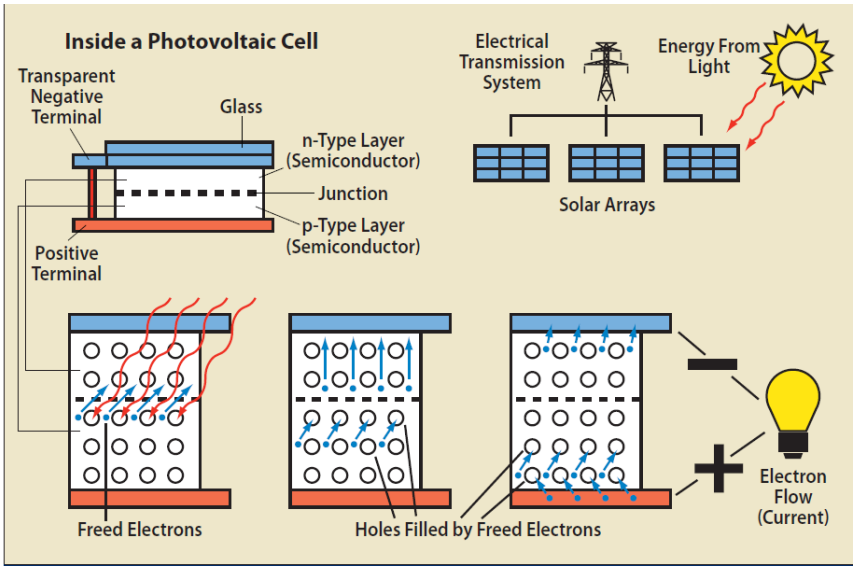

Supply Air Ductwork
Rotating Regenerator
Cold Outside Air
Warmed Air to Room
Cooled Exhaust Air
Warm Room Exhaust Air
Direction of Rotation
Exhaust Air Ductwork

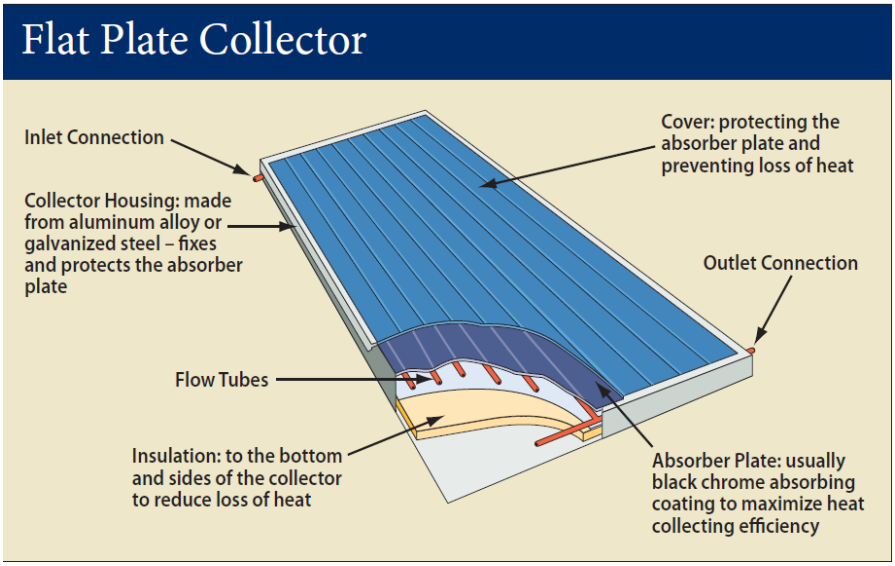

Vaporised fluid condenses and gives up heat
Heat in
Liquid
Vapour
Heat out
Metal mesh wick acts as return path for liquid working fluid
Heat evaporates working fluid

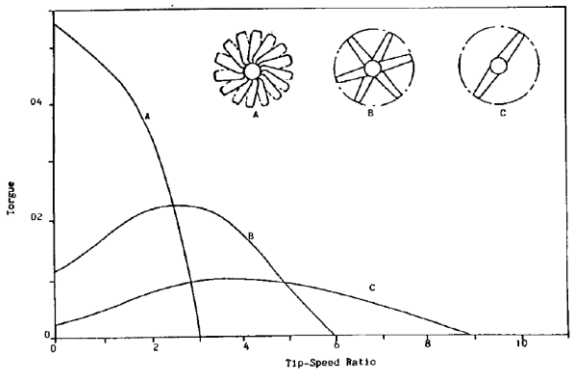

Shell
inlet
Tube
inlet
Tube
outlet
Shell
outlet


Directed heat out
Electricity in
High-pressure
vapour
High-pressure
liquid
Condenser
Compressor
Motor
Evaporator
Low-pressure
vapour
Low-pressure
liquid
Waste heat in

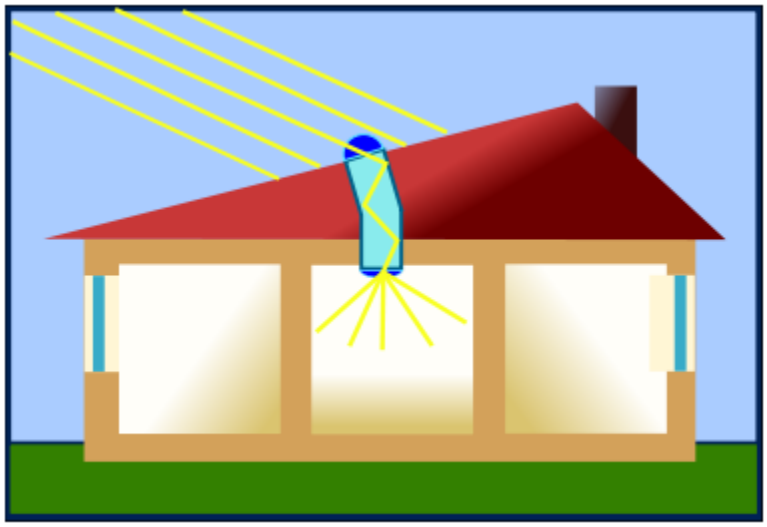

Insulated ceiling
Pelmet for heavy curtain
to be drawn after sunset
Direct and
reflected radiation
absorbed by
masonry walling
Low-angled
winter sun
penetrates
under eaves
Edge insulation in
extreme situations
North-facing, slab-on-ground
warmed by solar radiation
Winter

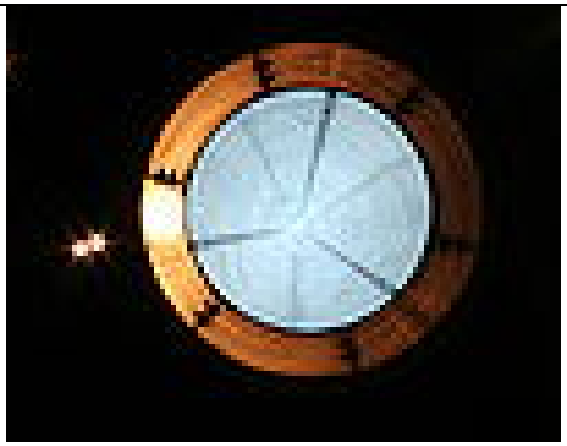


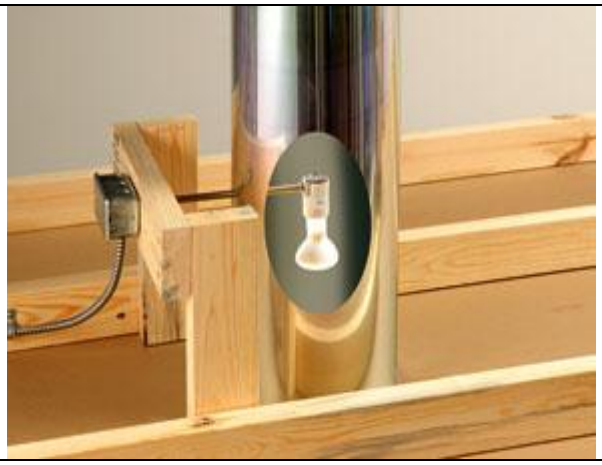




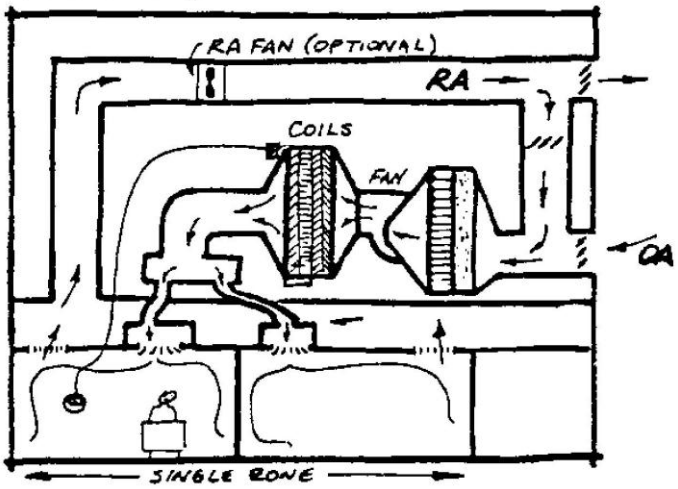
Solidity and torque

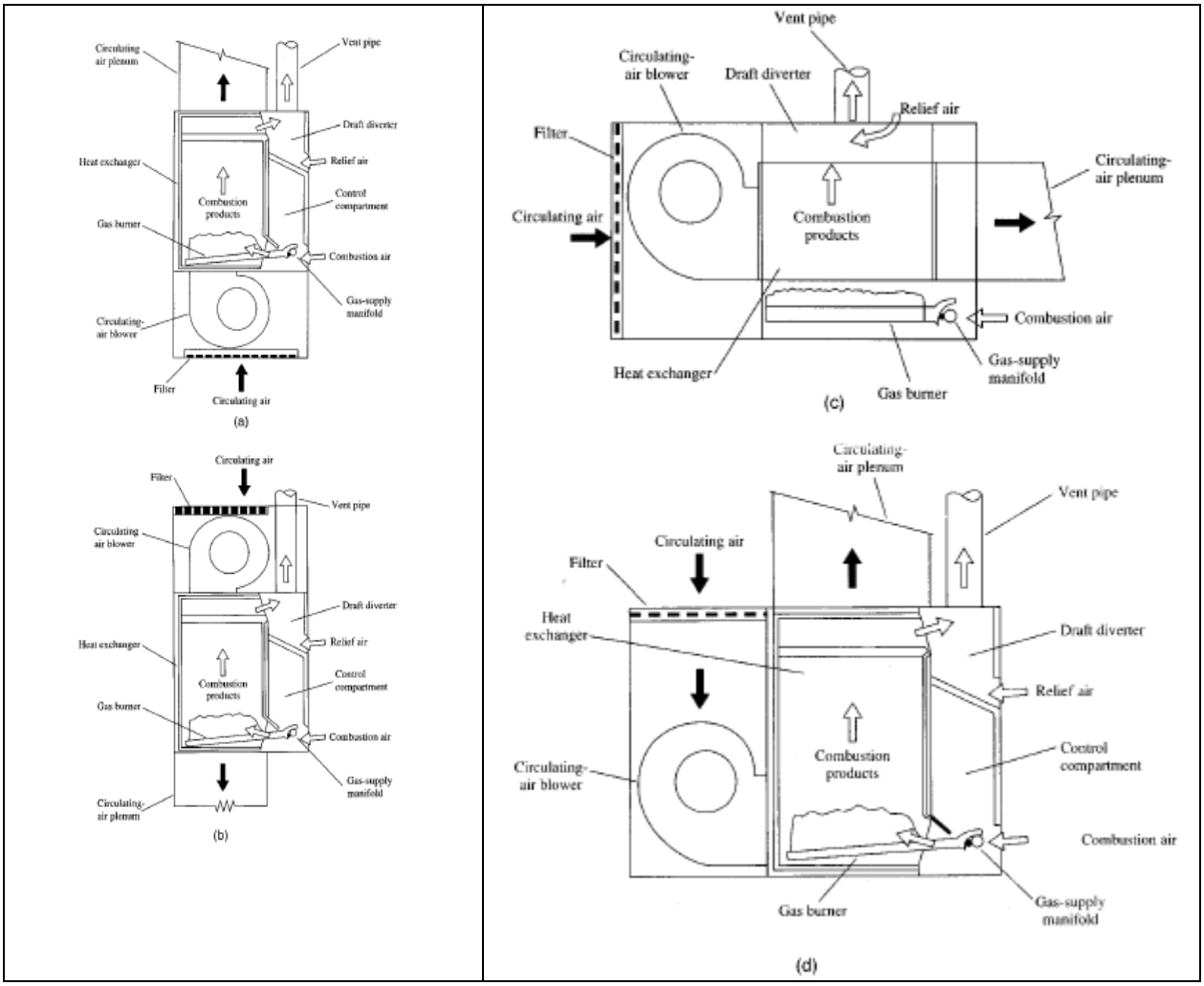


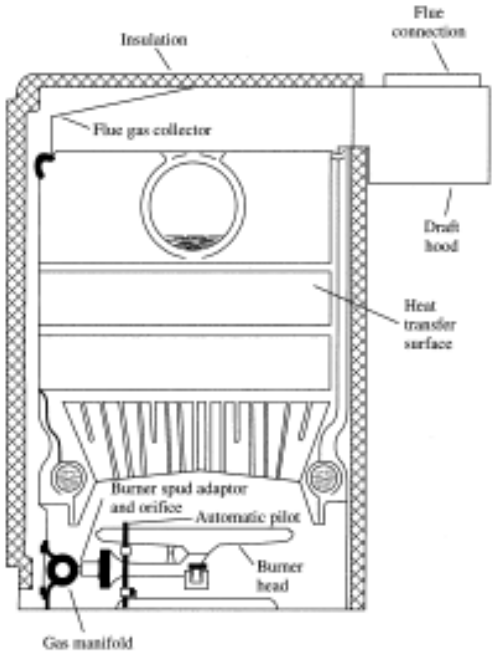




Basic HVAC System




Circulating air plenum
Vent pipe
Draft diverter
Relief air
Heat exchanger
Combustion products
Control compartment
Gas burner
Combustion air
Circulating-air blower
Gas-supply manifold
Filter
Circulating air
(a)
Circulating air
Filter
Vent pipe
Circulating air blower
Draft diverter
Relief air
Heat exchanger
Combustion products
Control compartment
Gas burner
Combustion air
Gas-supply manifold
Circulating-air plenum
(b)
Vent pipe
Circulating-air blower
Draft diverter
Relief air
Filter
Circulating air
Combustion products
Circulating-air plenum
Combustion air
Heat exchanger
Gas burner
Gas-supply manifold
(c)
Circulating-air plenum
Vent pipe
Circulating air
Filter
Heat exchanger
Draft diverter
Relief air
Circulating-air blower
Combustion products
Control compartment
Combustion air
Gas burner
Gas-supply manifold
(d)


Insulation
Flue connection
Flue gas collector
Draft hood
Heat transfer surface
Burner spud adaptor and orifice
Automatic pilot
Burner head
Gas manifold

Hot Water Demands and Use for Various Types of Buildings

Type of building[a]	Maximum hour	Maximum day	Average day
Men's dormitories	3.8 gal (14.4 L)/student	22.0 gal (83.4 L)/student	13.1 gal (49.7 L)/student
Women's dormitories	5.0 gal (19 L)/student	26.5 gal (100.4 L)/student	12.3 gal (46.6 L)/student
Motels: No. of units[a]			
20 or less	6.0 gal (22.7 L)/unit	35.0 gal (132.6 L)/unit	20.0 gal (75.8 L)/unit
60	5.0 gal (19.7 L)/unit	25.0 gal (94.8 L)/unit	14.0 gal (53.1 L)/unit
100 or more	4.0 gal (15.2 L)/unit	15.0 gal (56.8 L)/unit	10.0 gal (37.9 L)/unit
Nursing homes	4.5 gal (17.1 L)/bed	30.0 gal (113.7 L)/bed	18.4 gal (69.7 L)/bed
Office buildings	0.4 gal (1.5 L)/person	2.0 gal (7.6 L)/person	1.0 gal (3.8 L)/person
Food service establishments:			
Type A: full-meal restaurants and cafeterias	1.5 gal (5.7 L)/max meals/h	11.0 gal (41.7 L)/max meals/h	2.4 gal (9.1 L)/average meals/h[c]
Type B: drive-ins, grilles, luncheonettes, sandwich and snack shops	0.7 gal (2.6 L)/max meals/h	6.0 gal (22.7 L)/max meals/h	0.7 gal (2.6 L)/average meals/day[c]
Apartment houses: No. of apartments			
20 or less	12.0 gal (45.5 L)/apt.	80.0 gal (303.2 L)/apt.	42.0 gal (159.2 L)/apt.
50	10.0 gal (37.9 L)/apt.	73.0 gal (276.7 L)/apt.	40.0 gal (151.6 L)/apt.
75	8.5 gal (32.2 L)/apt.	66.0 gal (250 L)/apt.	38.0 gal (144 L)/apt.
100	7.0 gal (26.5 L)/apt.	60.0 gal (227.4 L)/apt.	37.0 gal (140.2 L)/apt.
200 or more	5.0 gal (19 L)/apt.	50.0 gal (195 L)/apt.	35.0 gal (132.7 L)/apt.
Elementary schools	0.6 gal (2.3 L)/student	1.5 gal (5.7 L)/student	0.6 gal (2.3 L)/student[b]
Junior and senior high schools	1.0 gal (3.8 L)/student	3.6 gal (13.6 L)/student	1.8 gal (6.8 L)/student[b]

[a] The average usage of a U.S. residence is 60 gal/day (227 L/h) with a peak usage of 6 gal/h (22.7 L/h) (ASHRAE, 1987).
[b] Interpolate for intermediate values.
[c] Per day of operation. Temperature basis: 140°F.
Source: From ASHRAE. With permission.

Representative Hot Water Use Temperatures

Use	Temperature	
	°F	°C
Lavatory		
Handwashing	105	40
Shaving	115	45
Showers and tubs	110	43
Therapeutic baths	95	35
Commercial and institutional laundry	180	82
Residential dishwashing and laundry	140	60
Surgical scrubbing	110	43
Commercial spray-type dishwashing		
Single or multiple tank hood(s) or rack(s)		
Wash	150 min	65 min
Final rinse	180–195	82–90
Single tank conveyor		
Wash	160 min	71 min
Final rinse	180–195	82–90

Note: Table values are water use temperatures, not necessarily water heater set points.

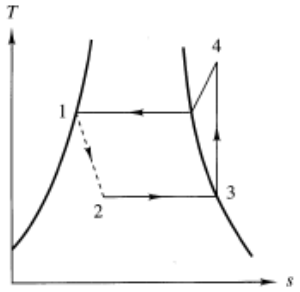


FIGURE 4.1.5 Heat pump T-s diagram showing four steps of the simple heat pump process. (From Rabl, A. and Kreider J.F., *Heating and Cooling of Buildings*, McGraw-Hill, New York, NY, 1994. With permission.)

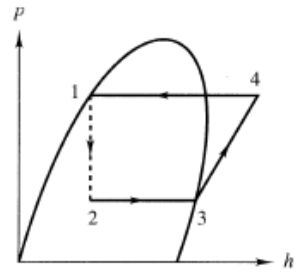


FIGURE 4.1.6 Heat pump p-h diagram showing four steps of the simple heat pump process. (From Rabl, A. and Kreider J.F., *Heating and Cooling of Buildings*, McGraw-Hill, New York, NY, 1994. With permission.)

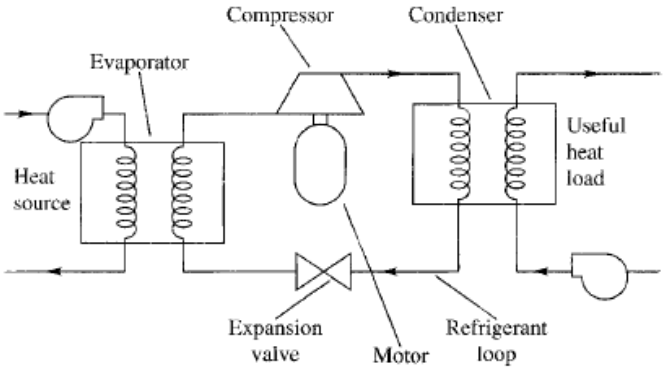
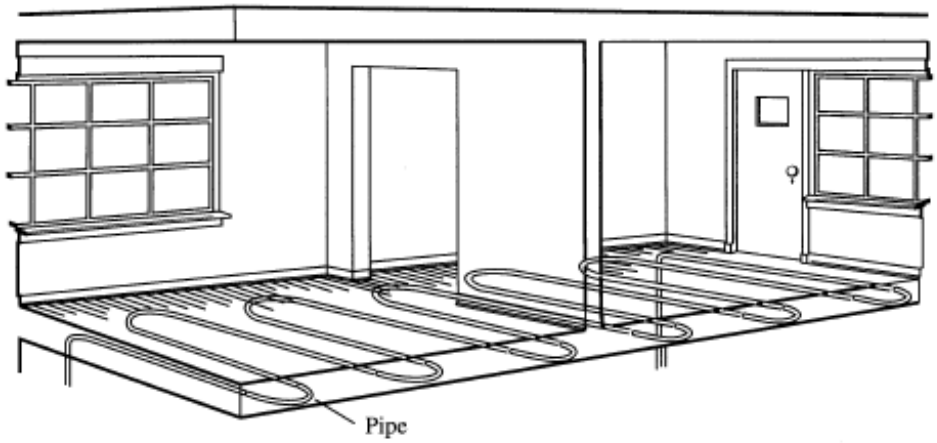


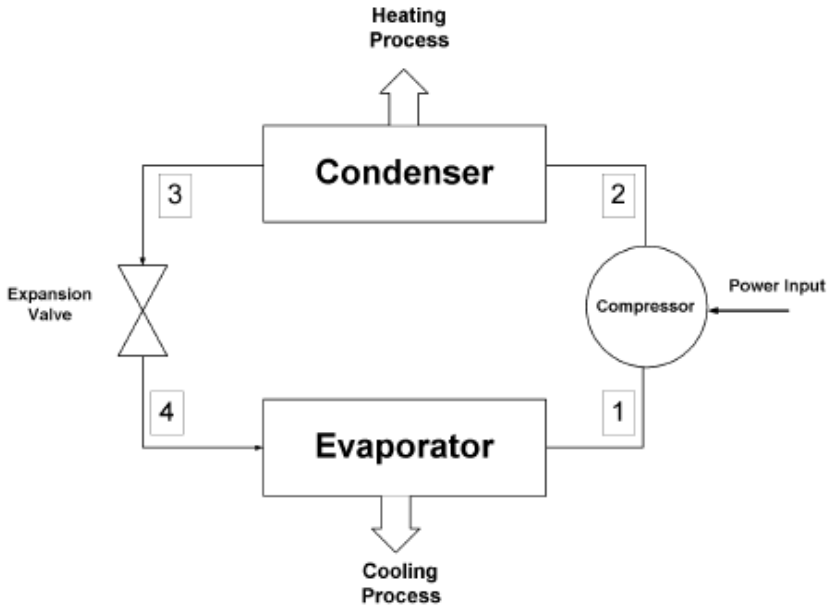
FIGURE 4.1.7 Liquid source heat pump mechanical equipment schematic diagram showing motor driven centrifugal compressor, condenser, and evaporator. (From Rabl, A. and Kreider J.F., *Heating and Cooling of Buildings*, McGraw-Hill, New York, NY, 1994. With permission.)

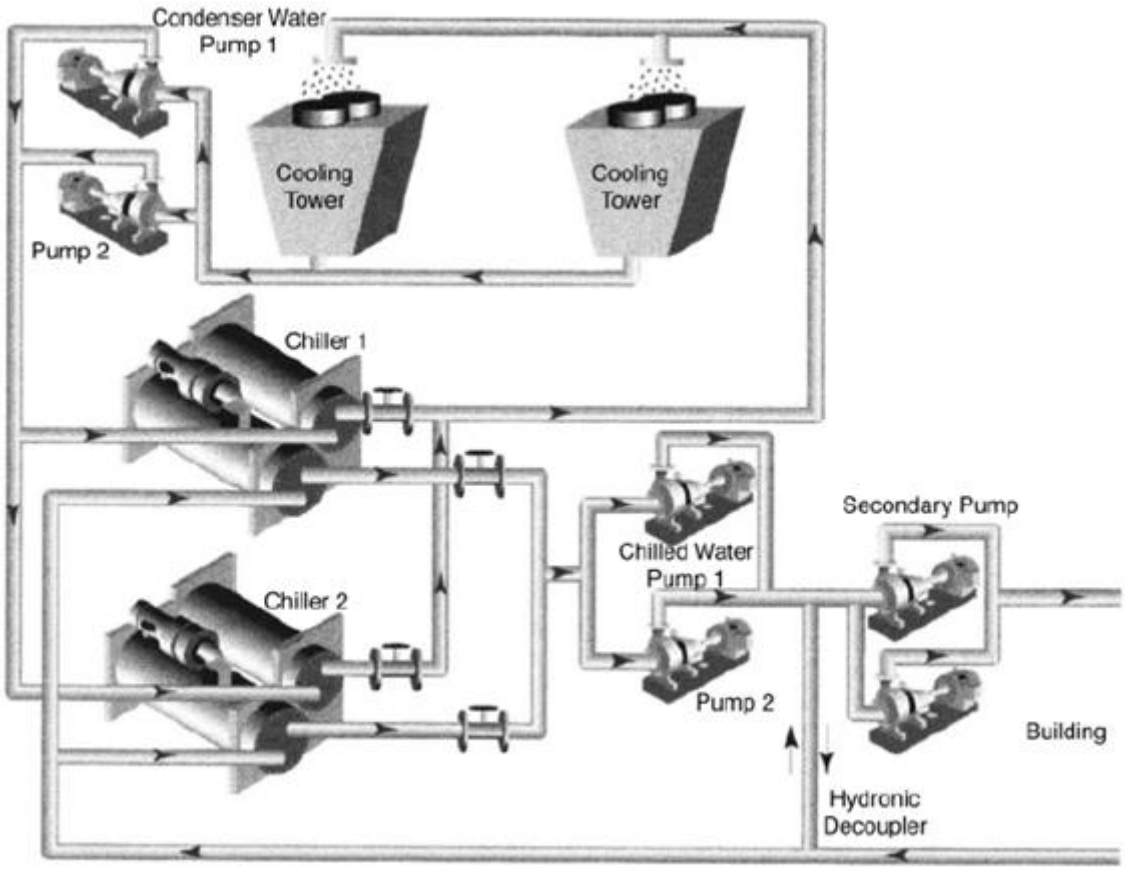
Advantages and Disadvantages of Air and Water Source Heat Pumps

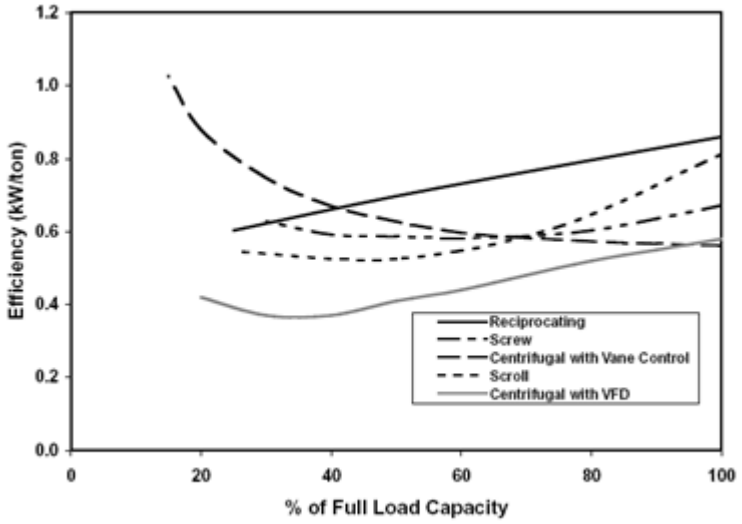
Type	Advantages	Disadvantages
Air source	Indoor distribution permits air conditioning and humidity control Outdoor air source readily available Simple installation Least expensive Established commercial technology	Defrost required Low capacity at cold outdoor temperature Lower efficiency because of large evaporator $\Delta T \approx 30°F$ Indoor air distribution temperature must be high for comfort reasons Reliability at low temperature is only fair, due to frosting effects Must keep evaporator clear of leaves, dirt, etc.
Water source	Multiple family and commercial installation as central system In commercial installations, good coupling to cooling towers No refrigerant reversal needed; reverse water flow instead	Needs water source at useful temperature Efficiency penalty due to space heat exchanger ΔT

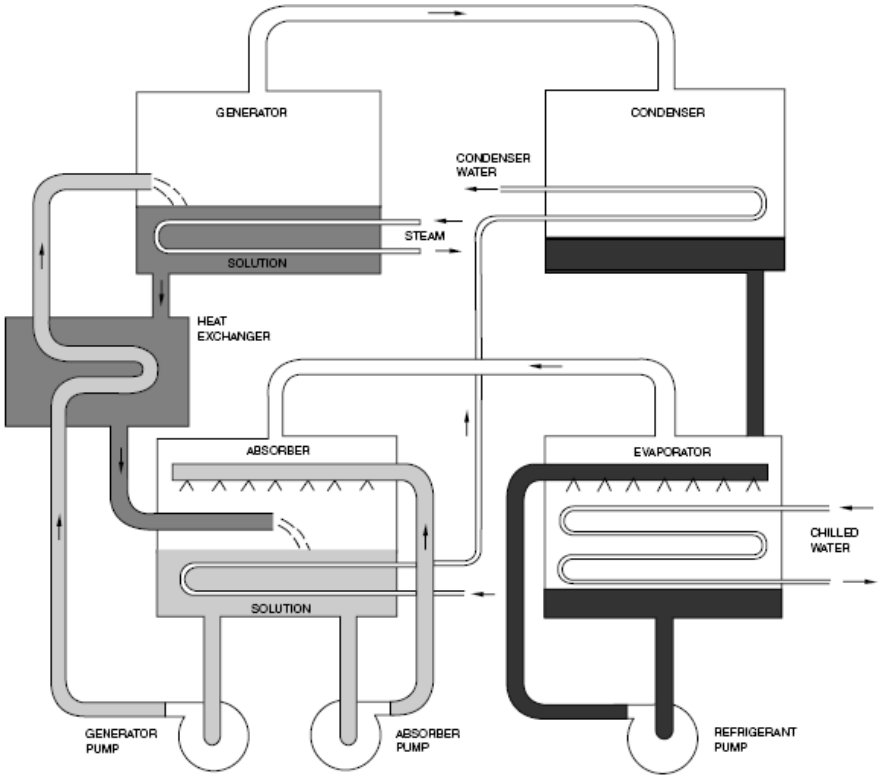


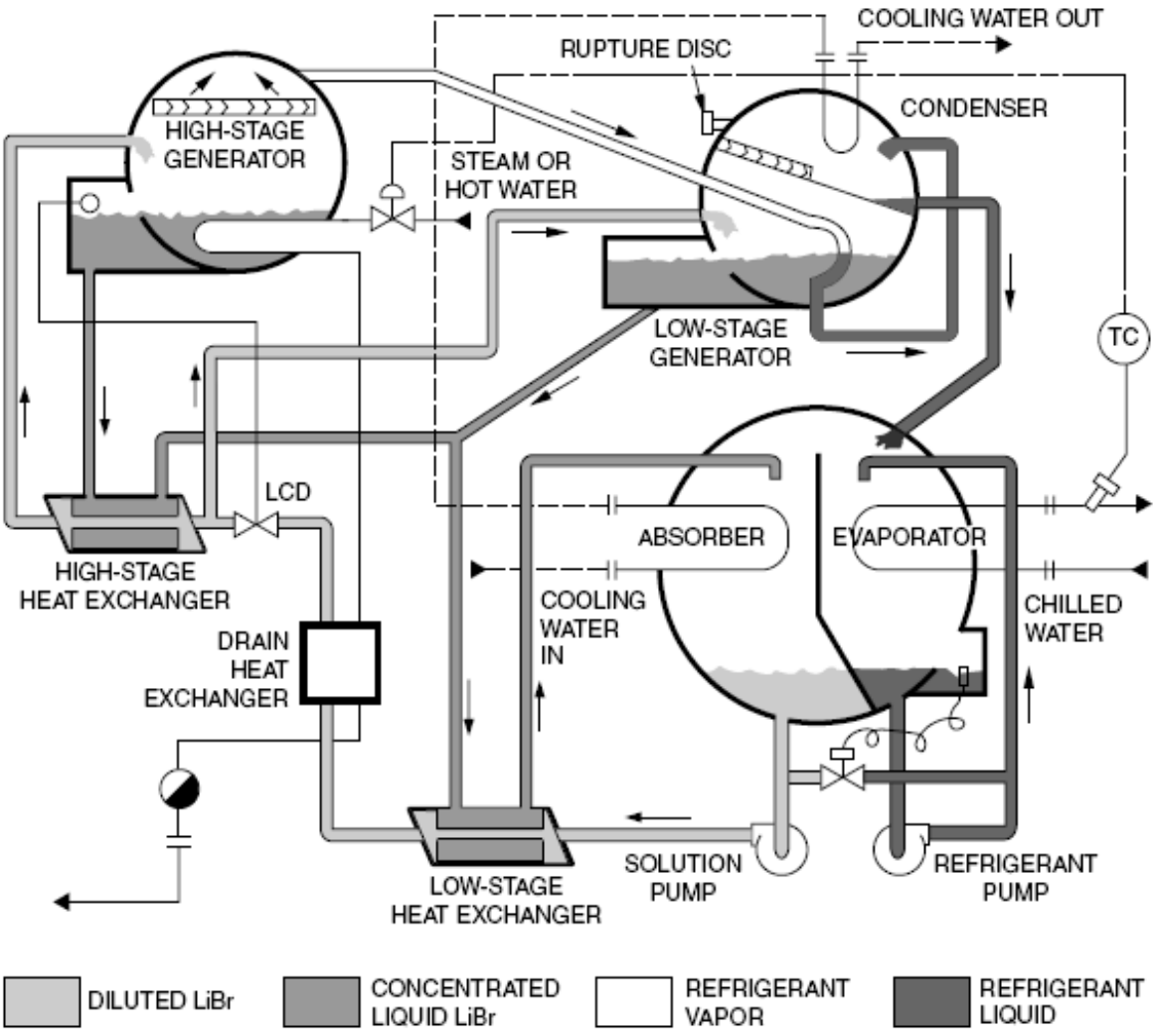
Residential radiant floor heating system.

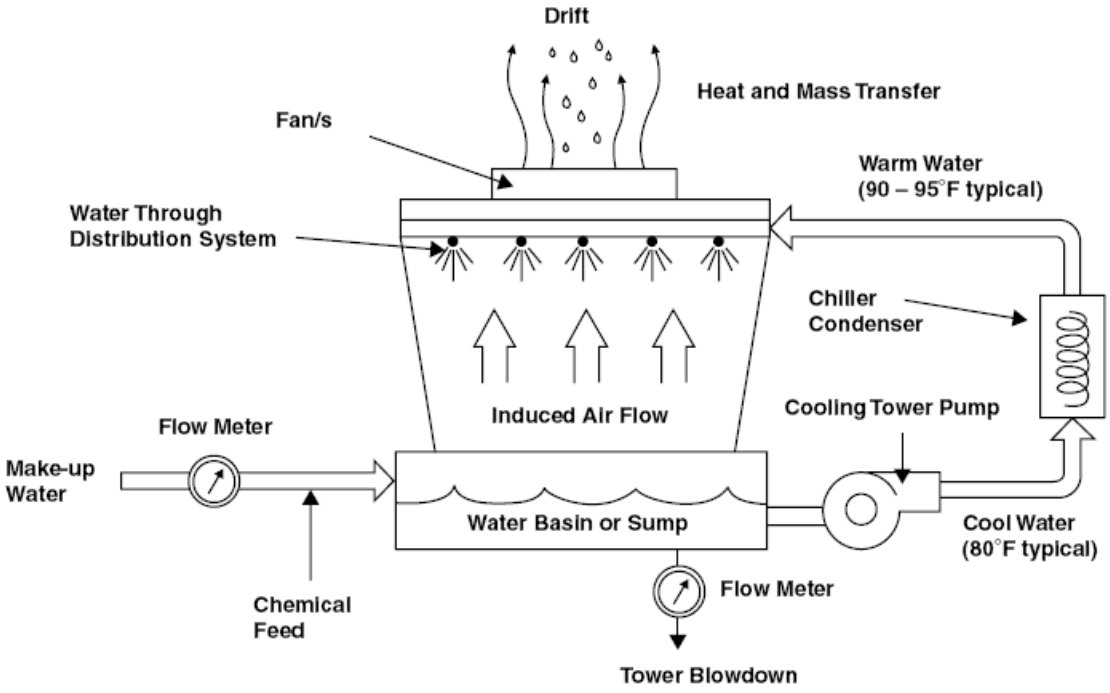

Heating Process
Condenser
3
2
Expansion Valve
Compressor
Power Input
4
Evaporator
1
Cooling Process

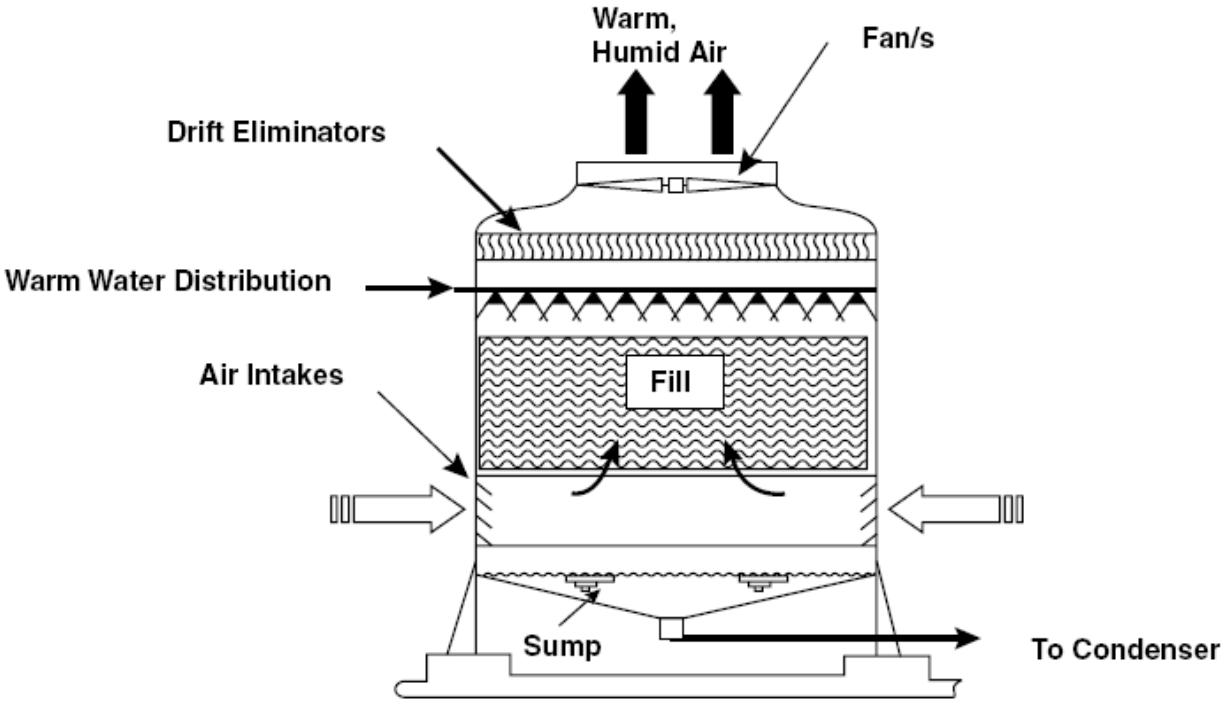

Condenser Water Pump 1
Cooling Tower
Cooling Tower
Pump 2
Chiller 1
Chiller 2
Chilled Water Pump 1
Pump 2
Secondary Pump
Building
Hydronic Decoupler

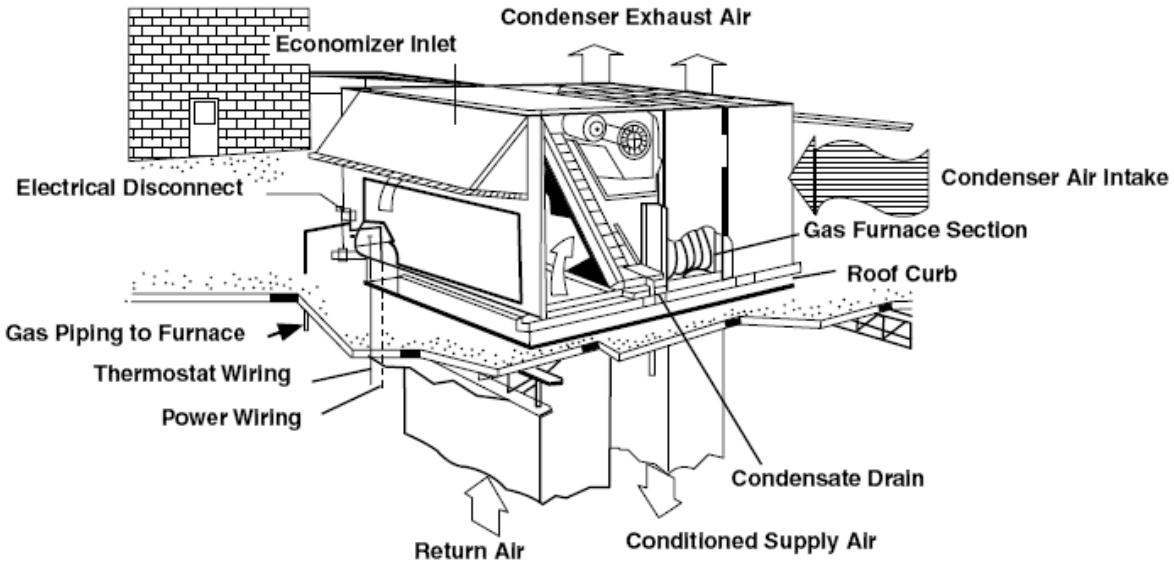

1.2
1.0
0.8
0.6
0.4
0.2
0.0
Efficiency (kW/ton)
0
20
40
60
80
100
% of Full Load Capacity
Reciprocating
Screw
Centrifugal with Vane Control
Scroll
Centrifugal with VFD

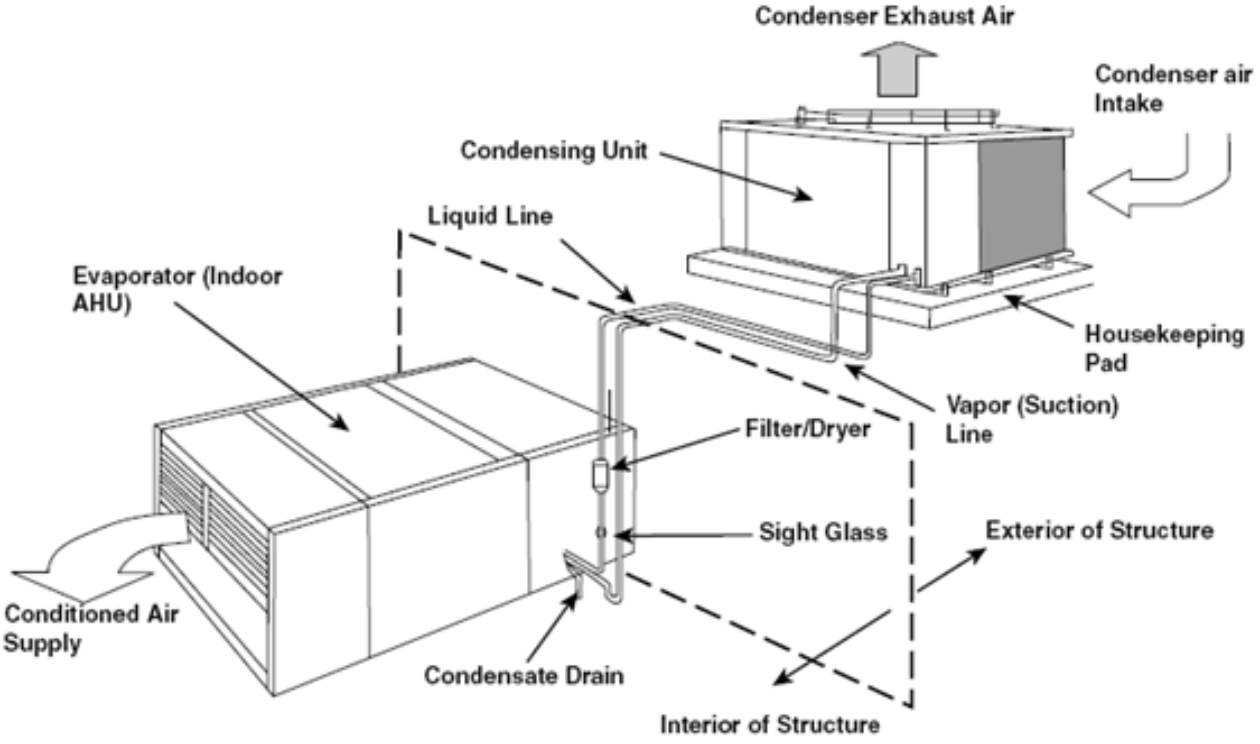

GENERATOR
CONDENSER
CONDENSER WATER
STEAM
SOLUTION
HEAT EXCHANGER
ABSORBER
EVAPORATOR
CHILLED WATER
SOLUTION
GENERATOR PUMP
ABSORBER PUMP
REFRIGERANT PUMP

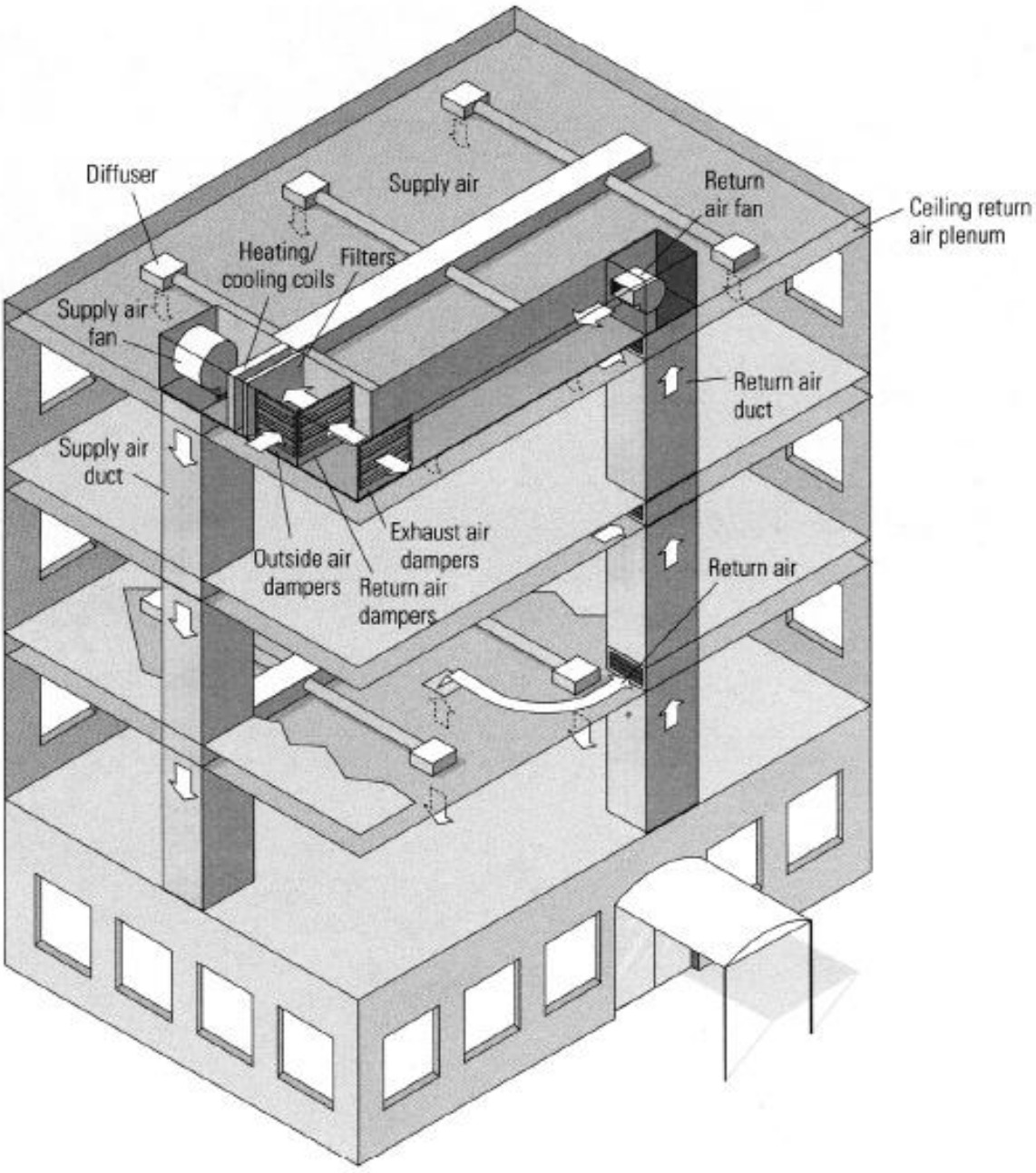

COOLING WATER OUT
RUPTURE DISC
CONDENSER
HIGH-STAGE GENERATOR
STEAM OR HOT WATER
LOW-STAGE GENERATOR
TC
LCD
ABSORBER
EVAPORATOR
HIGH-STAGE HEAT EXCHANGER
COOLING WATER IN
CHILLED WATER
DRAIN HEAT EXCHANGER
SOLUTION PUMP
REFRIGERANT PUMP
LOW-STAGE HEAT EXCHANGER
DILUTED LiBr
CONCENTRATED LIQUID LiBr
REFRIGERANT VAPOR
REFRIGERANT LIQUID

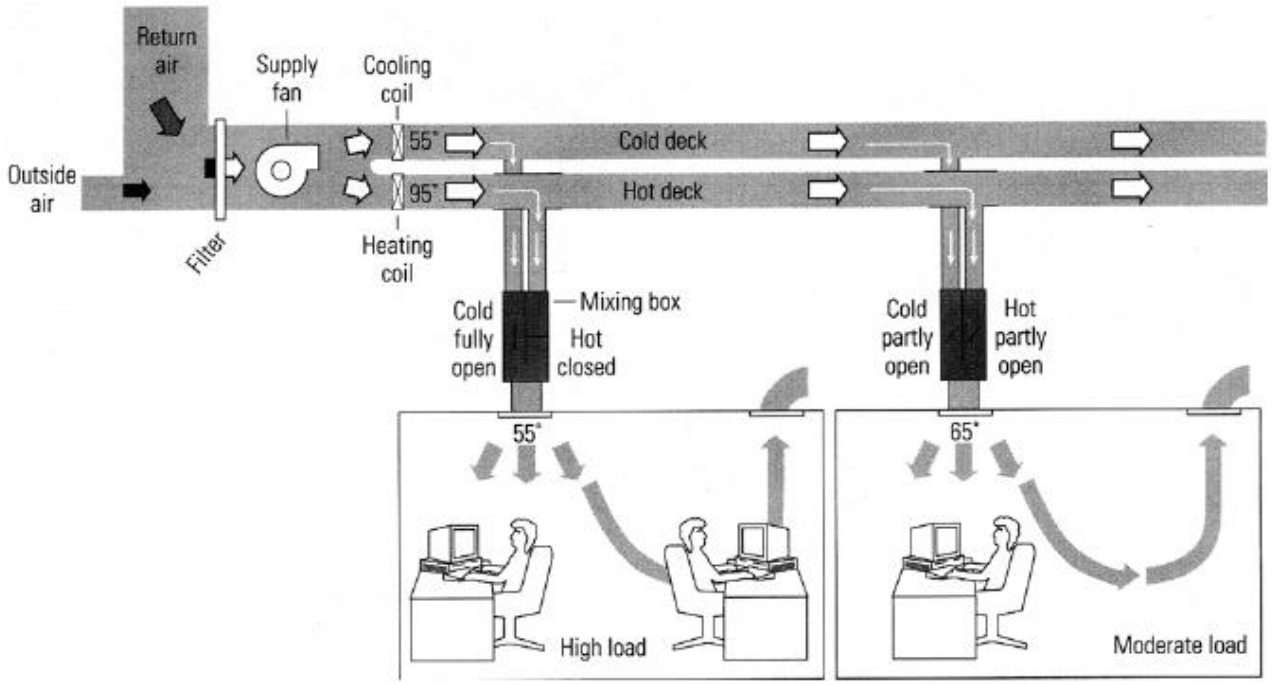

Drift
Heat and Mass Transfer
Fan/s
Warm Water
(90 – 95°F typical)
Water Through
Distribution System
Chiller
Condenser
Induced Air Flow
Cooling Tower Pump
Flow Meter
Make-up
Water
Water Basin or Sump
Cool Water
(80°F typical)
Chemical
Feed
Flow Meter
Tower Blowdown

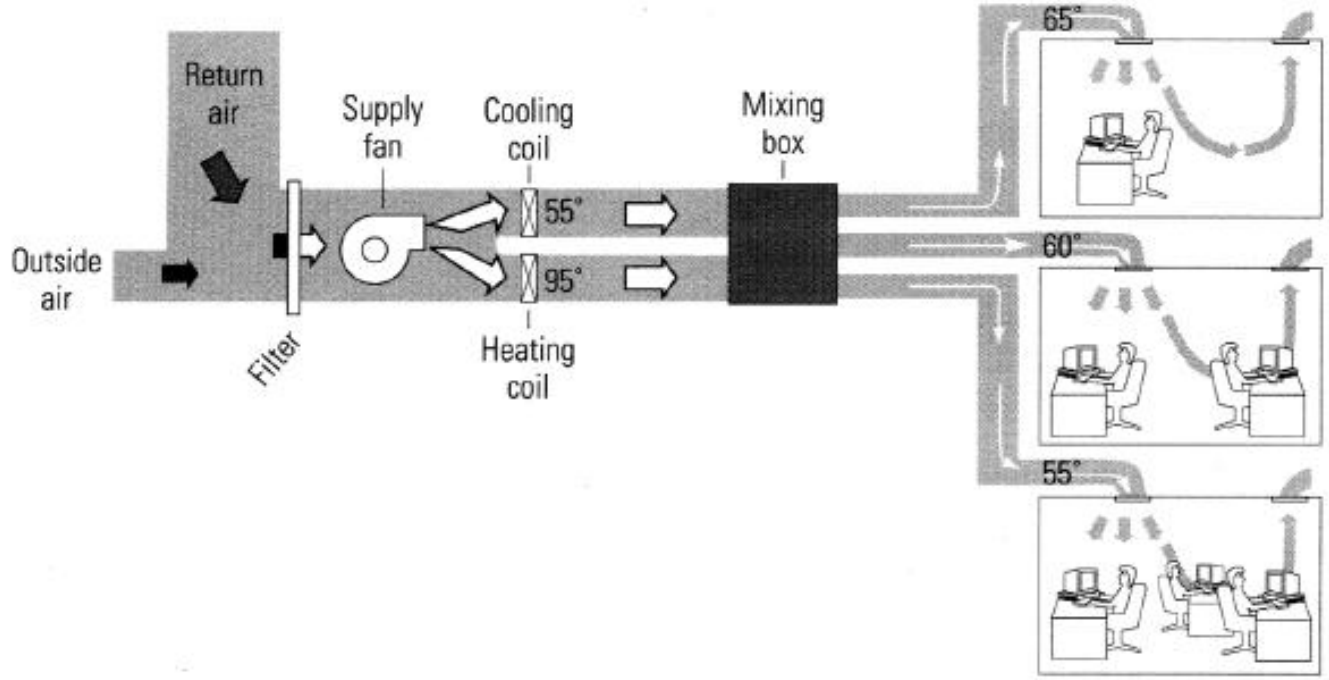

Warm,
Humid Air
Fan/s
Drift Eliminators
Warm Water Distribution
Air Intakes
Fill
Sump
To Condenser

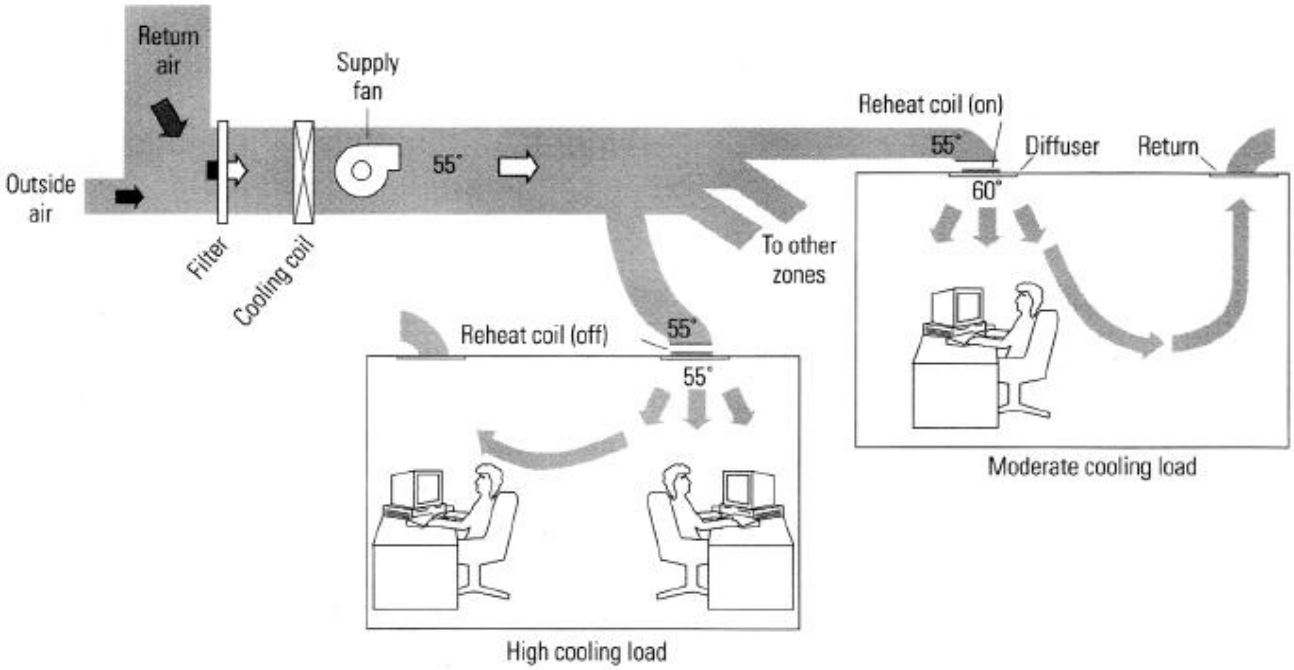

Condenser Exhaust Air
Economizer Inlet
Electrical Disconnect
Condenser Air Intake
Gas Furnace Section
Roof Curb
Gas Piping to Furnace
Thermostat Wiring
Power Wiring
Condensate Drain
Return Air
Conditioned Supply Air

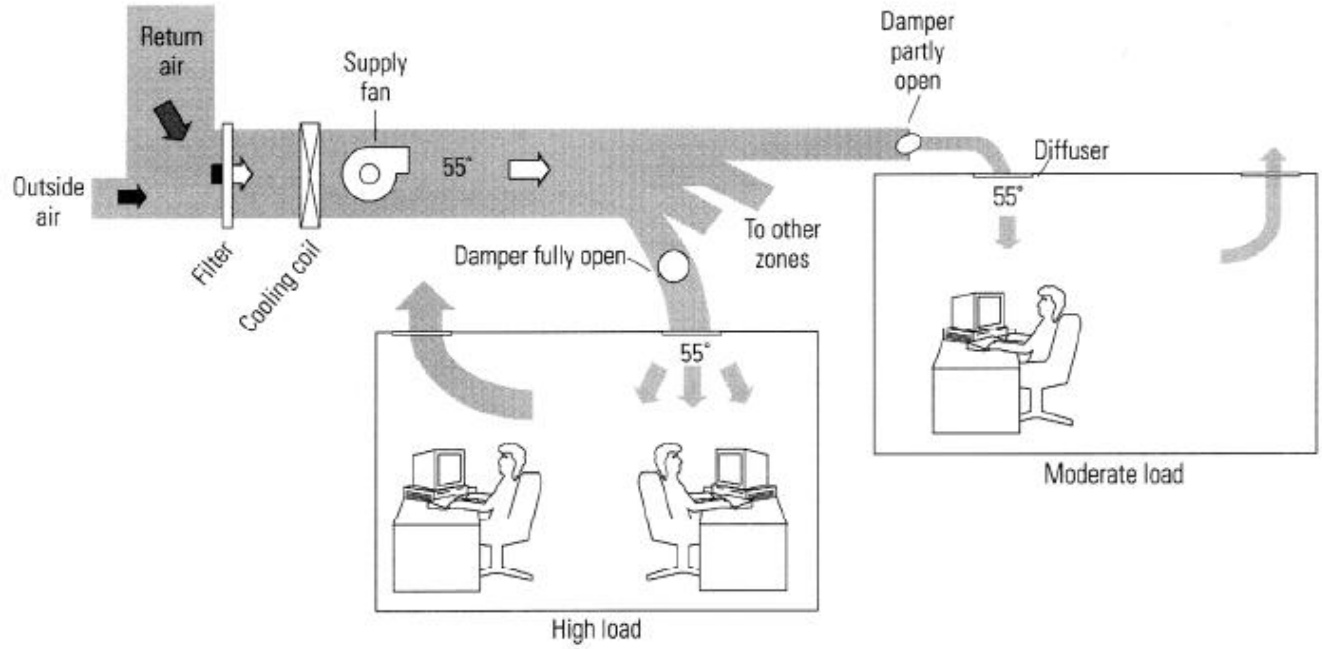

Condenser Exhaust Air
Condenser air Intake
Condensing Unit
Liquid Line
Evaporator (Indoor AHU)
Housekeeping Pad
Vapor (Suction) Line
Filter/Dryer
Sight Glass
Exterior of Structure
Conditioned Air Supply
Condensate Drain
Interior of Structure

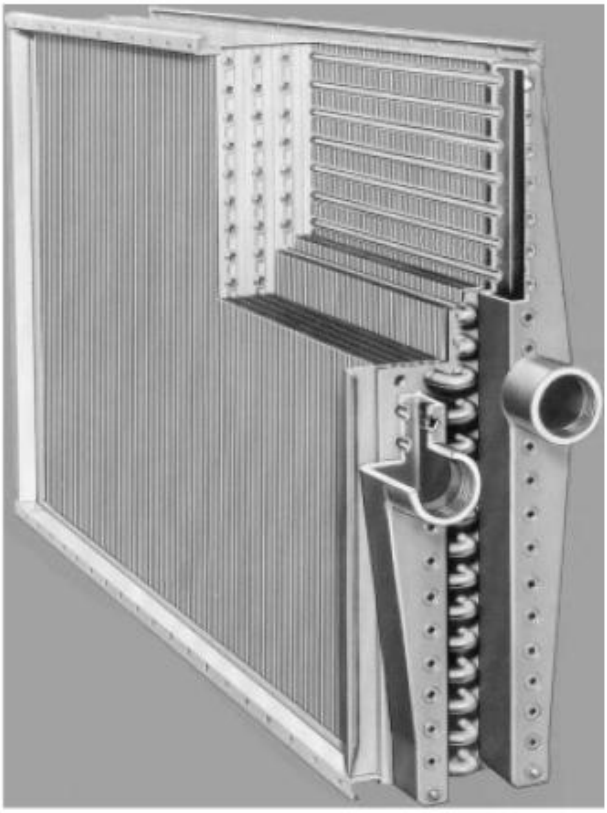

Diffuser
Supply air
Return air fan
Ceiling return air plenum
Heating/ cooling coils
Filters
Supply air fan
Return air duct
Supply air duct
Exhaust air dampers
Outside air dampers
Return air dampers
Return air

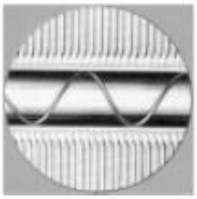

Return air
Supply fan
Cooling coil
Outside air
55°
95°
Cold deck
Hot deck
Filter
Heating coil
Mixing box
Cold fully open
Hot closed
Cold partly open
Hot partly open
55°
65°
High load
Moderate load

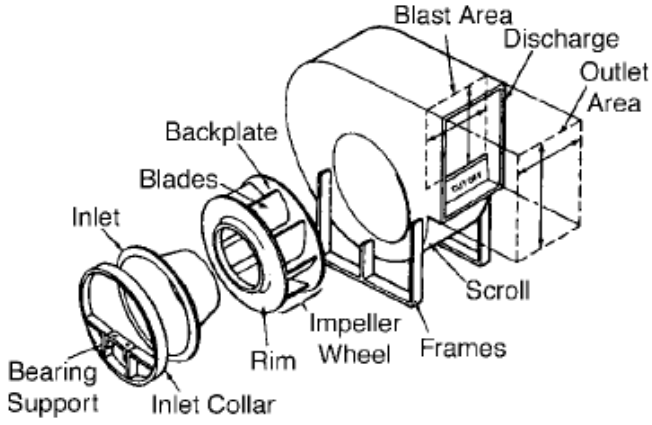

Return air
Supply fan
Cooling coil
Mixing box
Outside air
55°
95°
65°
60°
55°
Filter
Heating coil

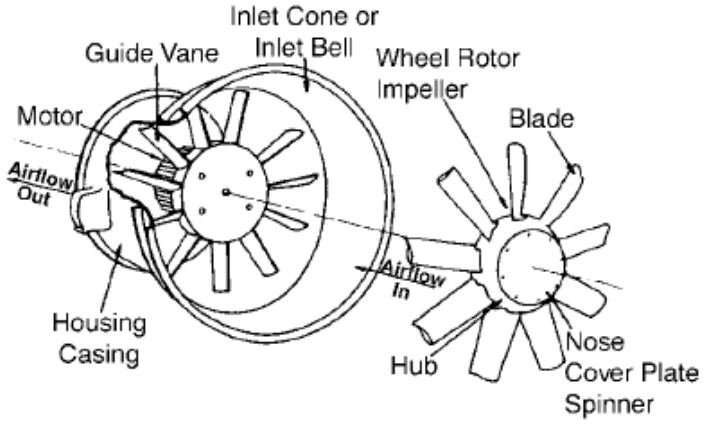

Return air
Supply fan
Reheat coil (on)
55°
Diffuser
Return
Outside air
55°
60°
Filter
Cooling coil
To other zones
Reheat coil (off)
55°
55°
Moderate cooling load
High cooling load

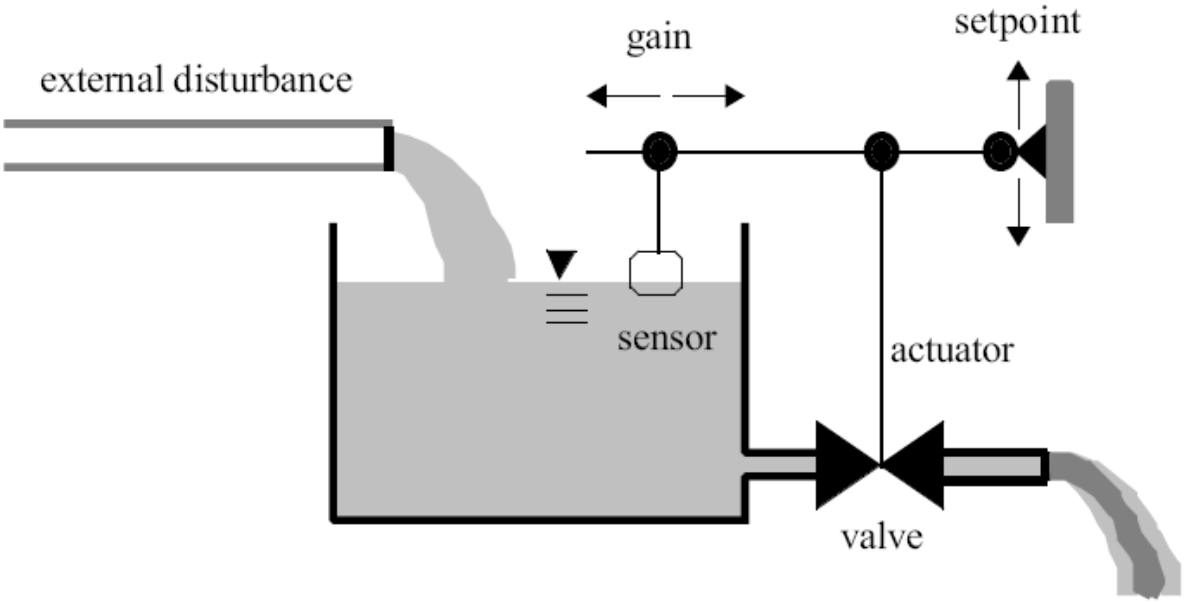

Return air
Supply fan
Damper partly open
Diffuser
55°
Outside air
55°
To other zones
Filter
Cooling coil
Damper fully open
55°
Moderate load
High load





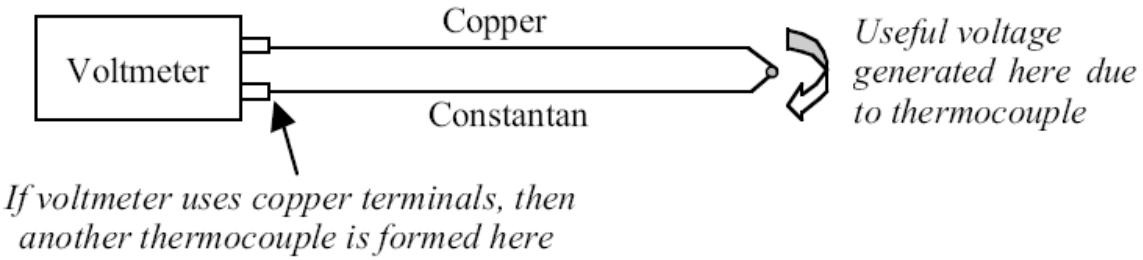

Blast Area
Discharge
Outlet
Area
Backplate
Blades
Inlet
Scroll
Impeller
Wheel
Rim
Frames
Bearing
Support
Inlet Collar

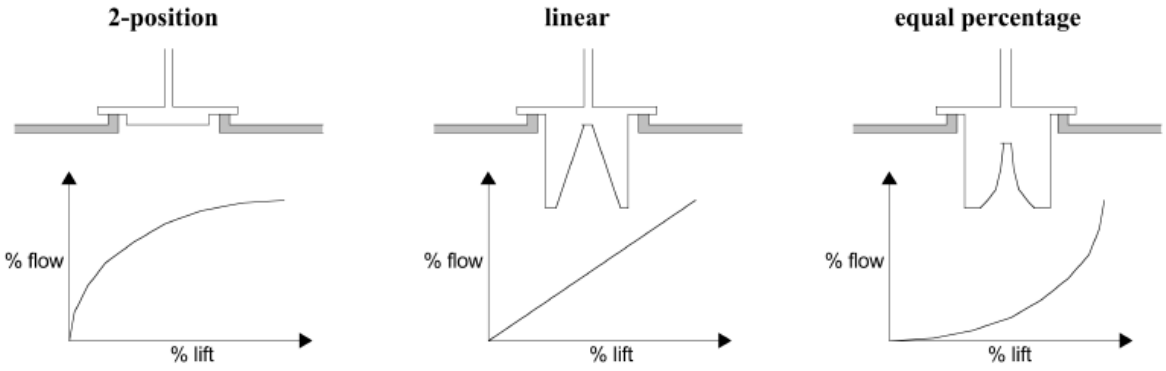

Inlet Cone or
Inlet Bell
Guide Vane
Wheel Rotor
Impeller
Blade
Motor
Airflow
Out
Airflow
In
Housing
Casing
Hub
Nose
Cover Plate
Spinner

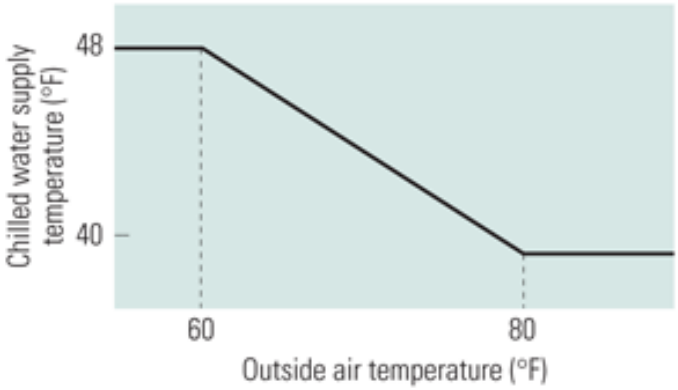


Thermocouple Types and Ranges

Type	Metals +	Metals –	Average Seebeck Coefficient μV/°F	Average Seebeck Coefficient ref. °F	Std. Error °F	Range °F
B	94% Pt/6% Rh	70% Pt/30% Rh	3.3	1112	7.9–15.5	32 to 3200
E	90% Ni/10% Cr	Constantan	32.5	32	3.1–7.9	–450 to 1800
J	Iron	Constantan	27.9	32	2.0–5.2	–350 to 1400
K	90% Ni/10% Cr	Ni	21.9	32	2.0–5.2	–450 to 2400
R	87% Pt/10% Rh	Pt	6.4	1112	2.5–6.8	–60 to 3100
S	90% Pt/10% Rh	Pt	5.7	1112	2.5–6.8	–60 to 3100
T	Cu	Constantan	21.1	32	1.4–5.2	–450 to 800

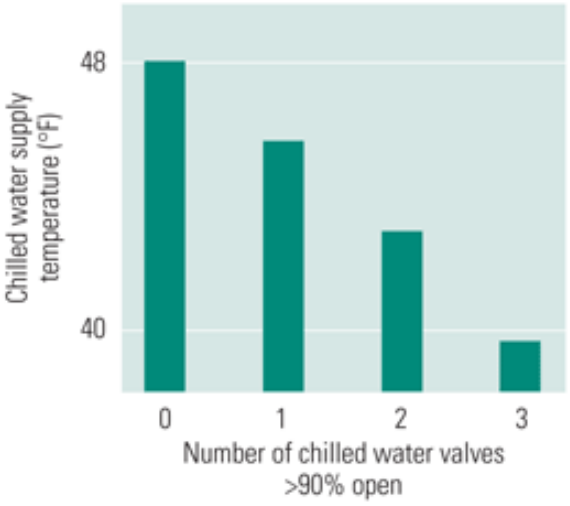






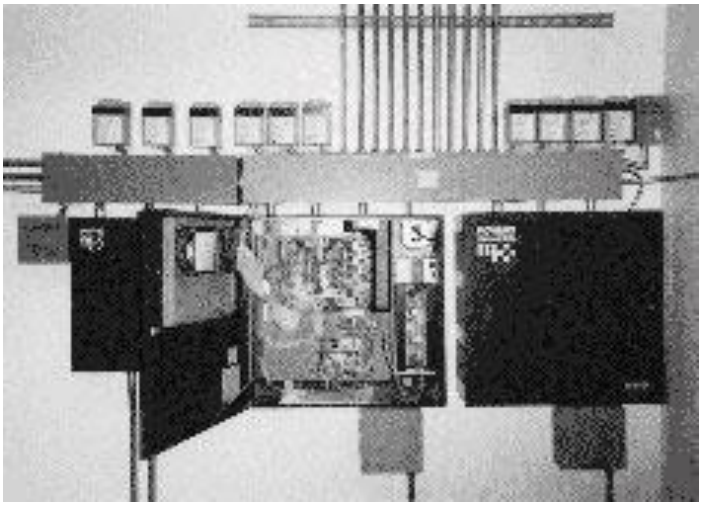
Notes: F = Fahrenheit.

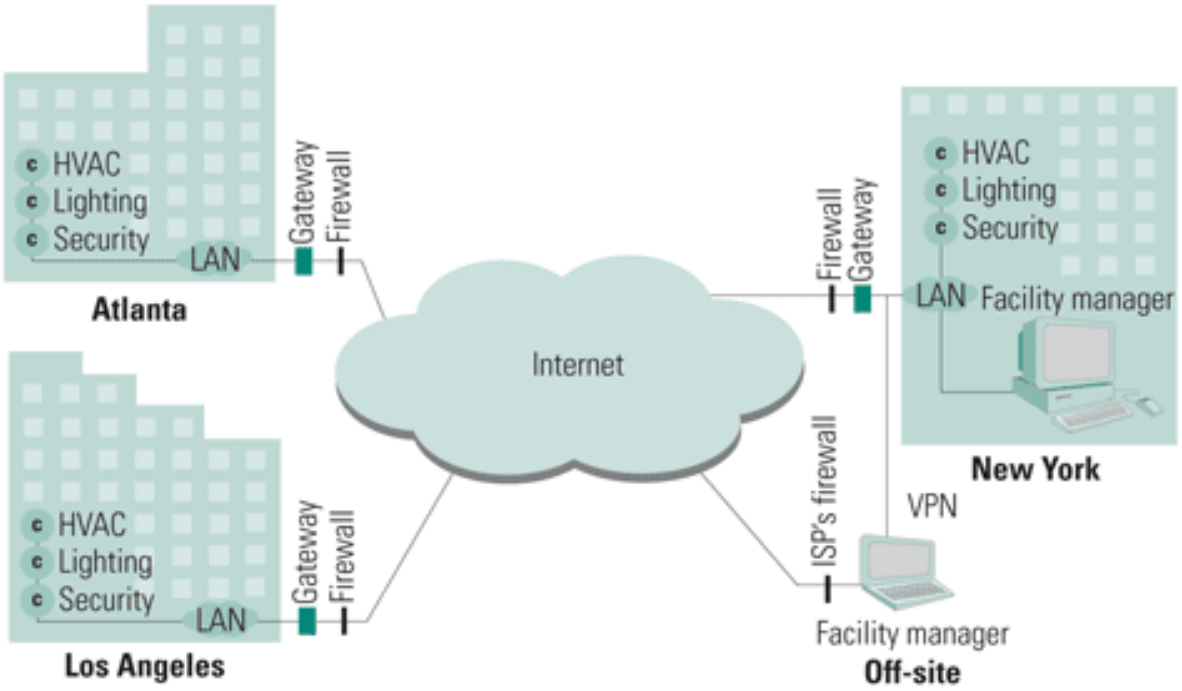
Source: Platts; adapted from Portland Energy Conservation Inc.



Notes: F = Fahrenheit.

Source: Platts; adapted from Portland Energy Conservation Inc.





Notes: ISP = Internet service provider;
LAN = Local area network;
VPN = Virtual private network.

Source: Platts